Computational and Collaborative tools for Composite Materials

National Materials Advisory Board

24-25 November 2003

Gail Hahn

The Boeing Company

314-233-1848

gail.l.hahn@boeing.com

Accelerated Insertion of Materials – Composites (AIM-C)

Jointly accomplished by a Boeing Led Team and the U.S. Government under the guidance of the Office of Naval Aviation Systems Technology

Dr. Leo Christodoulou of DARPA/DSO **Dr. Raymond J. Meilunas, NAVAIR**

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **NOV 2003**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **Computational and Collaborative tools for Composite Materials**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **The Boeing Company**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**13**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

AIM-C Alignment Tool

The objective of the AIM-C Program is to provide concepts, an approach, and tools that can accelerate the insertion of composite materials into DoD systems.

AIM-C Accomplishes This Three Ways

Methodology - ***Evaluates the historical roadblocks to effective implementation of composites and offers a process or protocol to eliminate these roadblocks and a strategy to expand the use of the systems and processes developed.***

Product Development - **Provides** ***a software tool that facilitates evaluation of composite materials for various applications.***

Demonstration/Validation - ***Provides a mechanism for acceptance by primary users of the system and validation by those responsible for certification of the applications in which the new materials may be used.***

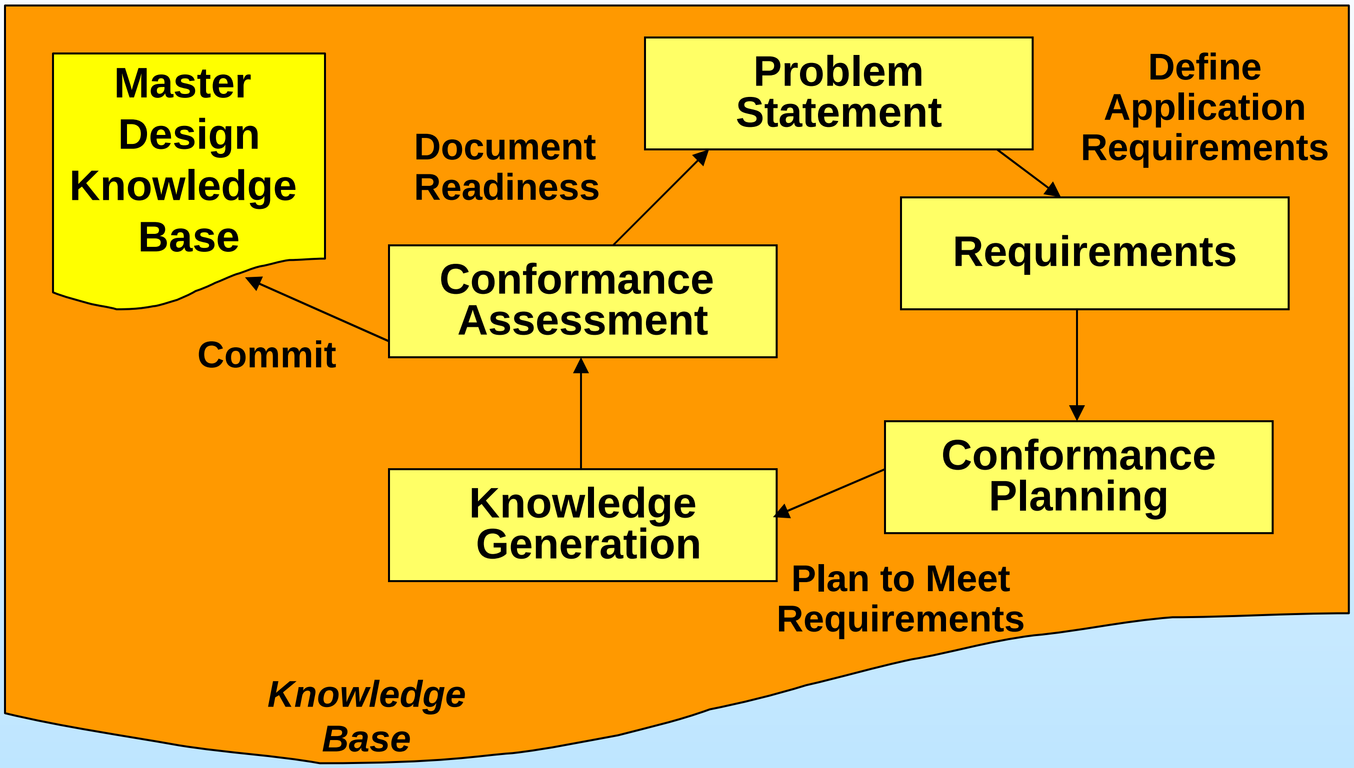
All tasks in Phase 1 support development of a Phase 2 Transition Program

Accelerated Insertion of Materials Is Achieved in AIM-C Methodology by

- Focusing on Real Insertion Needs (Designer Knowledge Base)
- Approach for coordinated use of
  - Existing Knowledge
  - Validated Analysis tools
  - Focused Testing
- Application of Physics Based Material & Structural Analysis Methods
- Use of Integrated Engineering Processes & Simulations
- Uncertainty Analysis and Management
  - Early Feature Based Demonstration
  - Tracking of Variability and Error Propagation Across Scales
- Rework Avoidance
- Disciplined approach for pedigree management

Orchestrated Knowledge Management to efficiently tie together the above elements to DKB

How Does the IPT Use AIM-C Methodology?



Knowledge Gathering

Technology Readiness Levels

Detail or “x” Readiness Levels

Exit Criteria

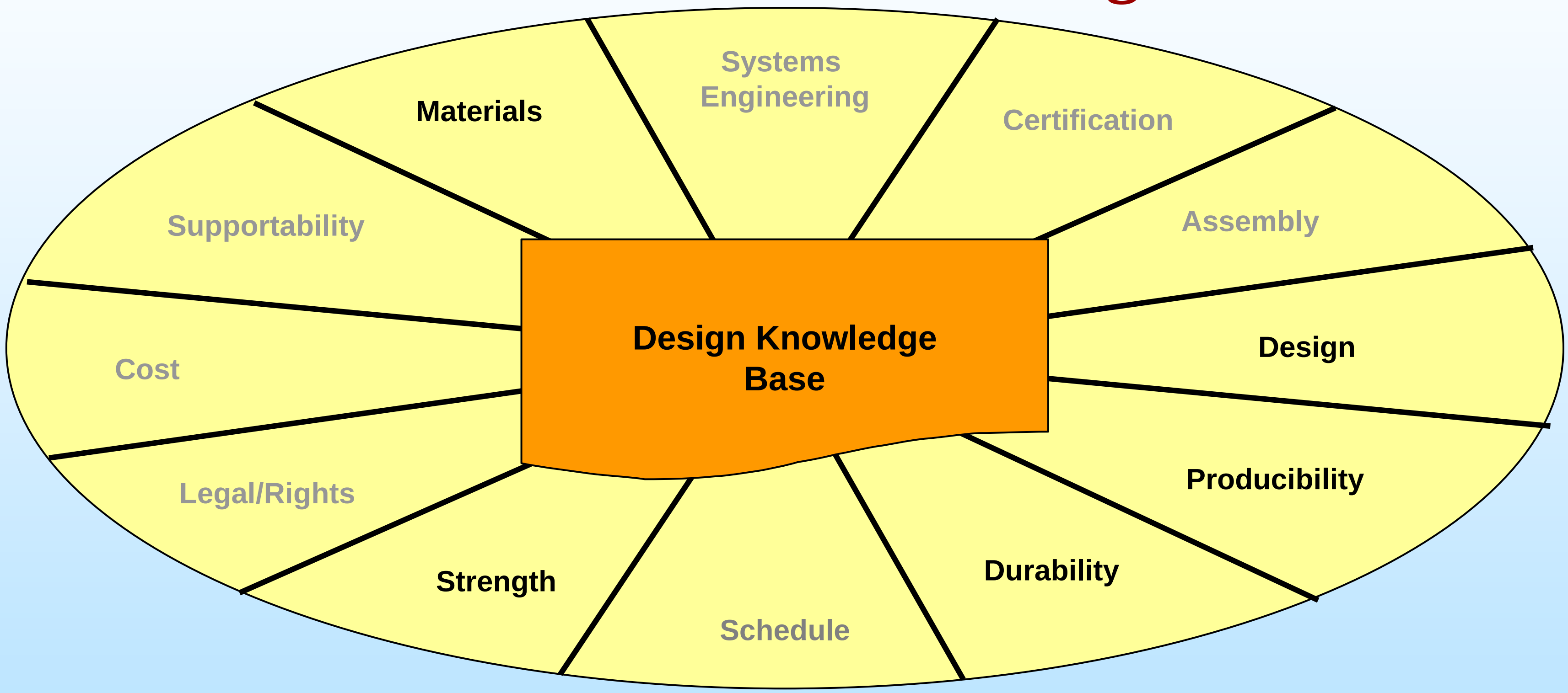
Worksheet

- Use of Prior Knowledge
- Recommended Analyses
- Recommended Tests
- Recommended Combination of Prior Knowledge / Analysis /Test

The Same Linkage Used To Flow Down Requirements Is Used to Roll Up Knowledge And Track Progress as Designer Knowledge is Gathered.

Integrated Product Team Chooses How To Meet Each Exit Criteria

The AIM-C Process Uses an Integrated Product Team to Commit Data to the Knowledge Base

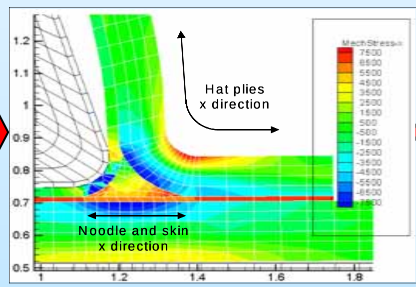


Use of AIM-C

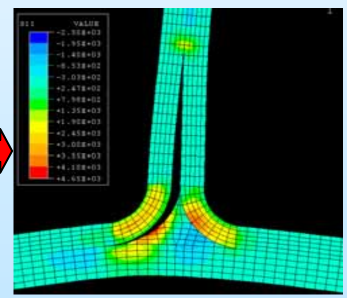
Web-Based System Delivery

Process Guidance and Risk Reduction Status

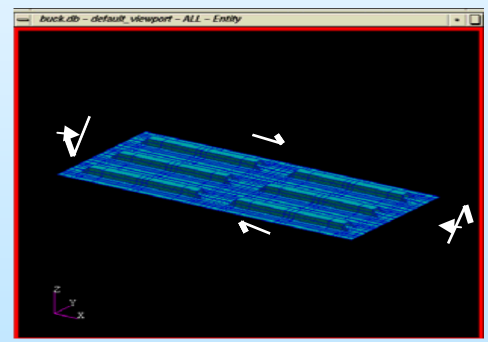
AIM-C Contains Analytical Models From Constituents



To Processing



To Effects of Defects



To Structural Reqs.

To Provide Analysis Supported by Test To Technology Readiness

•Approved for Public Release, Distribution Unlimited

Handling Uncertainty – The AIM-C Approach

- The First Step is Identifying and Understanding potential error sources
  - Maintains Visibility of potential errors
  - Forces step-by-step breakdown of the analysis/test process
  - Forces agreement on responses of interest

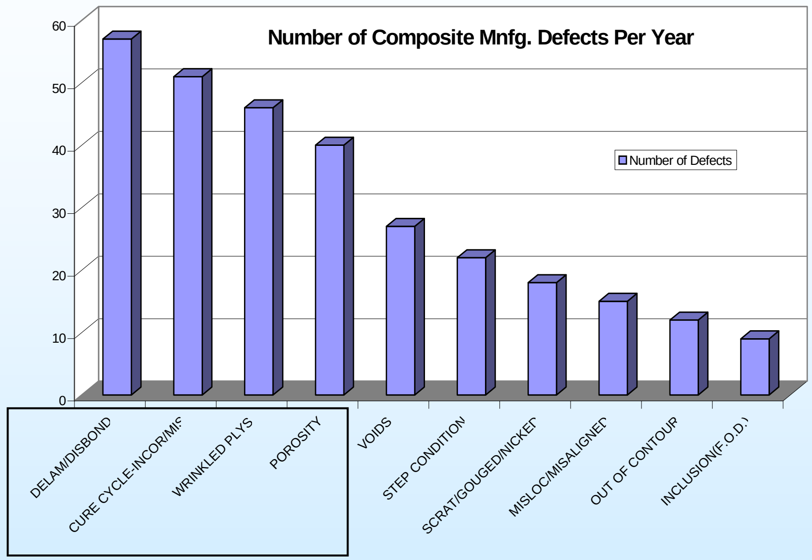
- Classifying them allows the team to determine appropriate strategies for addressing them.

- Types:
  - Aleatory Uncertainty (Variability, Stochastic Uncertainty)
  - Epistemic Uncertainty (Lack of Knowledge, e.g., unknown geometry)
  - Known Errors (e.g., mesh convergence, round-off error)
  - Unknown Errors (Mistakes, e.g. wrong material inputs used)

Handling Uncertainty – The AIM-C Approach

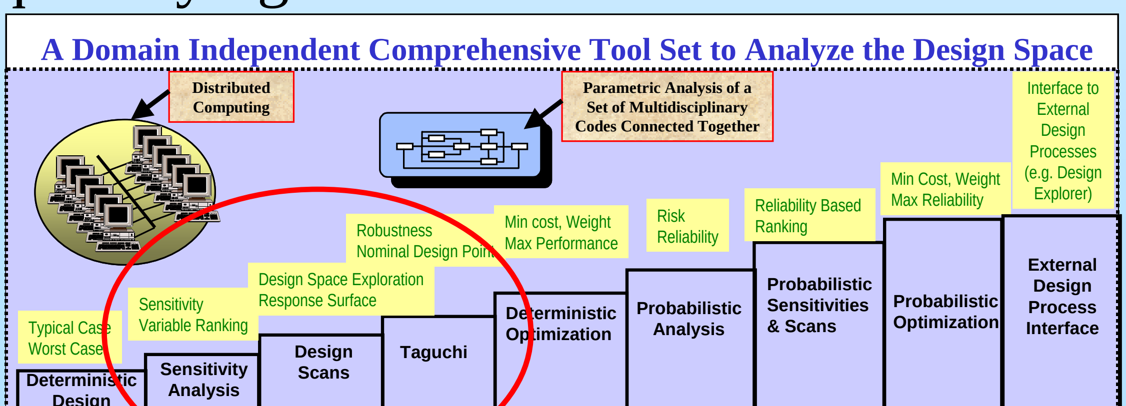
- Prior knowledge is useful in determining likelihood of occurrence.

Example: Past experience with Similar designs suggest that 3/4 of Stiffened panel defects are:
- Delaminations
- Cure Cycle Inconformities
- Ply wrinkles, or
- Voids/Porosity



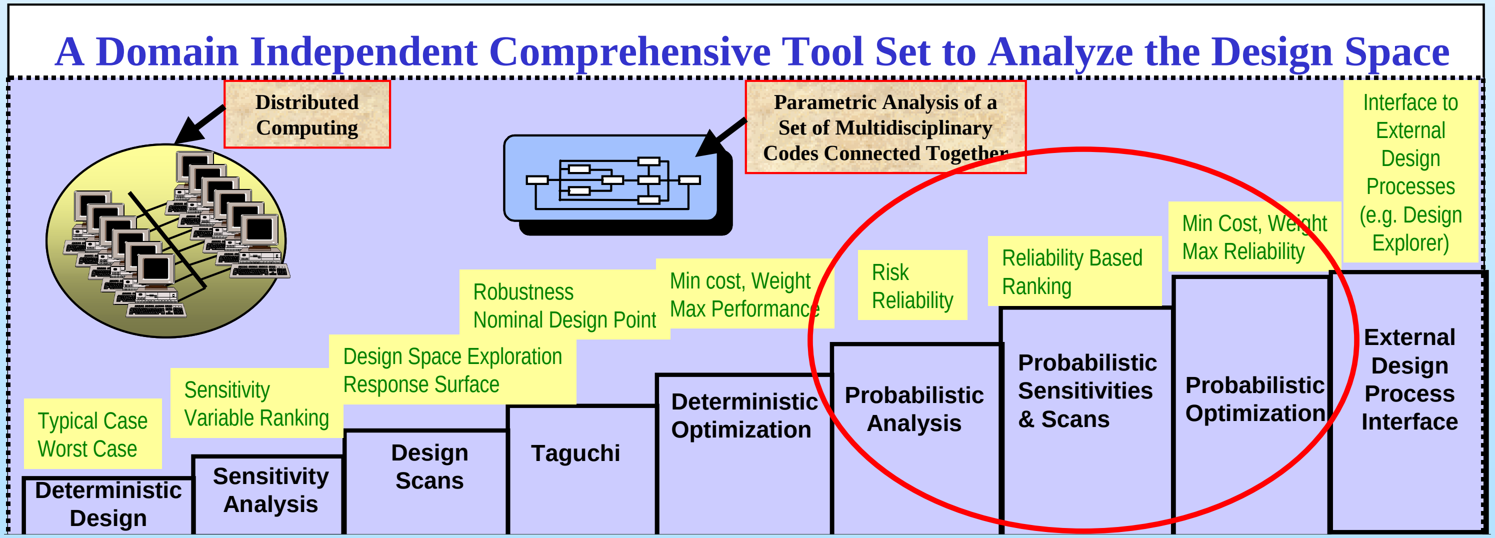
- Tools such as DOE/ANOVA and Sensitivity Analysis are useful in quantifying a variable's influence on the result.

Robust Design Computational System (RDCS)



Handling Uncertainty – The AIM-C Approach
Quantifying Uncertainty

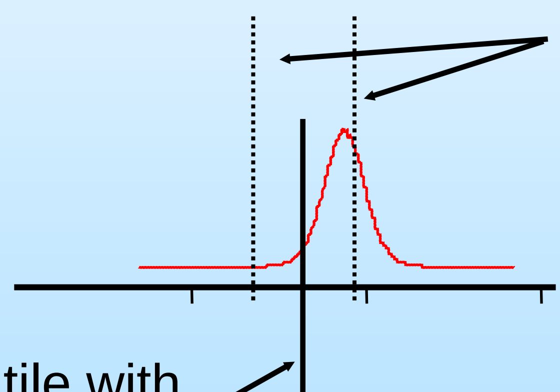
- If its important, and you can't remove it by design, quantify it.
- Testing or Probabilistic Analysis Tools are applied.



Data from Knowledge, Analysis, and Test
Combined Data – Allowables with Uncertainty

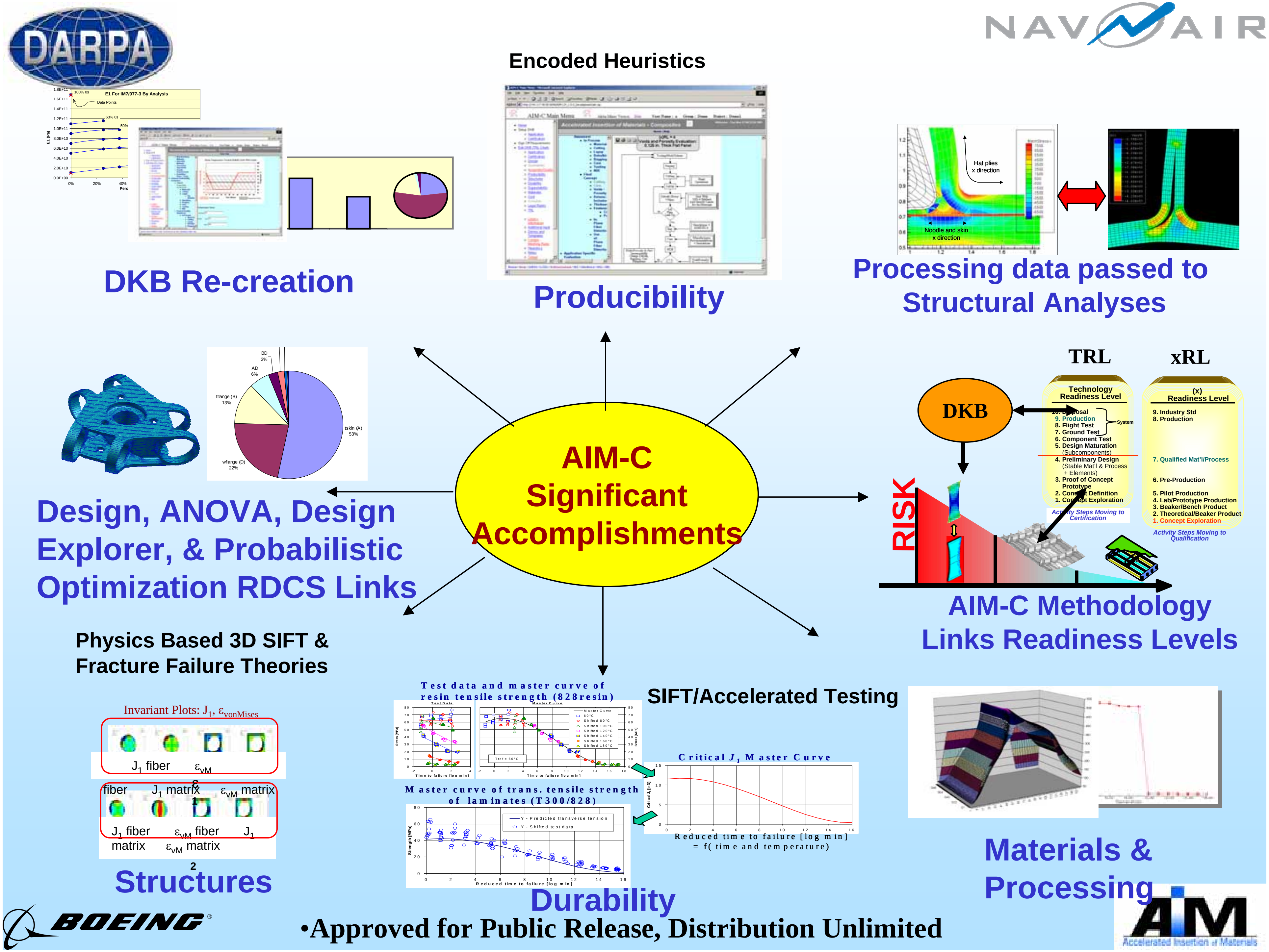
- Data contain replicates => can estimate stress allowables (quantiles with confidence bands)
- RDCS allows simulation of physical data with sources of randomness including batch effects (aleatory or random uncertainty) => can simulate allowables.
- Combined data: allowables with uncertainty bands

Bayesian uncertainty band on allowable



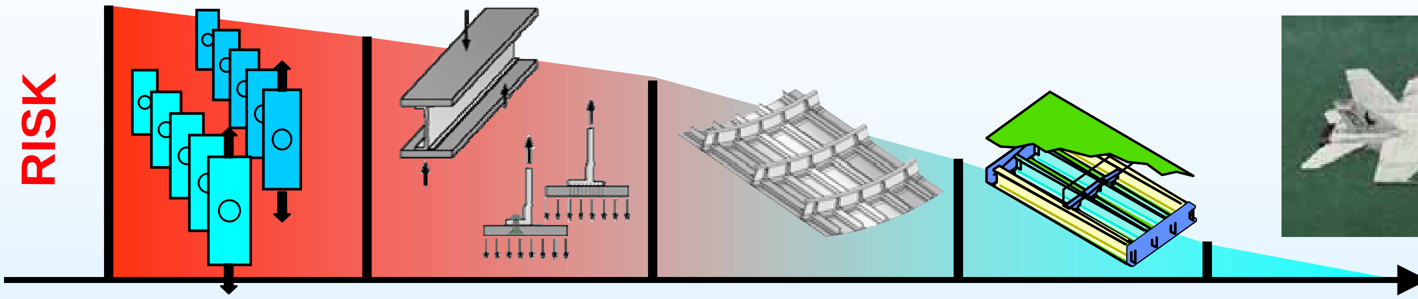
Allowable estimate = quantile with confidence band. This is the "aleatory" content

Aleatory and Bayesian are kept separate


DARPA
NAVAIR
Encoded Heuristics
DKB Re-creation
Producibility
Processing data passed to Structural Analyses
Hat plies x direction
Noodle and skin x direction
TRL
xRL
DKB
Technology Readiness Level
(x) Readiness Level
RISK
AIM-C Significant Accomplishments
Design, ANOVA, Design Explorer, & Probabilistic Optimization RDCS Links
AIM-C Methodology Links Readiness Levels
Physics Based 3D SIFT & Fracture Failure Theories
Invariant Plots: J1, εvonMises
Structures
Test data and master curve of resin tensile strength (828resin)
Master curve of trans. tensile strength of laminates (T300/828)
SIFT/Accelerated Testing
Critical J1 Master Curve
Reduced time to failure [log min] = f(time and temperature)
Durability
Materials & Processing
BOEING
•Approved for Public Release, Distribution Unlimited
AIM Accelerated Insertion of Materials

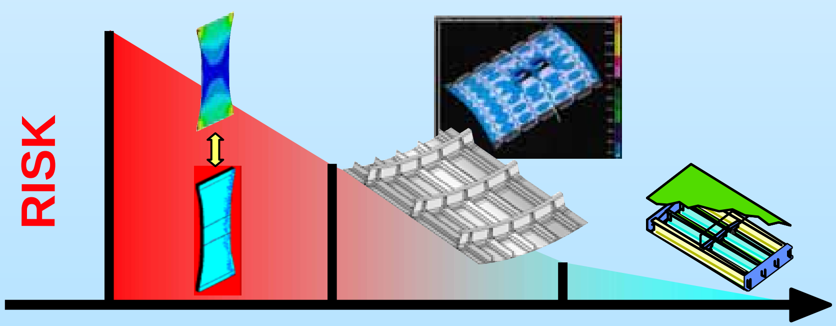
What's the Benefit of AIM-C?

Traditional Test Supported by Analysis Approach



Time to Insertion Readiness

AIM Provides an Analysis Approach Supported by Experience, Test and Demonstration



Time to Insertion Readiness
Reduced by 55%

GP14294001.ppt

•Approved for Public Release, Distribution Unlimited